IMPROVEMENT OF ABSOLUTE DISTANCE ESTIMATION UNDER WATER: USE OF MONOCULAR MOTION PARALLAX

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SUMMARY PAGE

THE PROBLEM

To determine if monocular motion parallax improves the accuracy of distance estimation under water.

FINDINGS

Training with feedback was again shown to be very effective for improving distance estimation, but the additional advantage of using motion parallax was too small to be of practical value.

APPLICATION

The most effective training procedure for divers is practice with feedback, as previously reported.

ADMINISTRATIVE INFORMATION

This investigation was conducted as part of Bureau of Medicine and Surgery Research Unit M4306.03-2050DXC5. The present report is Number 15 on this work unit. It was submitted for review on 22 Feb 1973, approved for publication on 1 March 1973 and designated as NavSubMedRschLab Report No. 740.

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ABSTRACT

The possible value of monocular motion parallax for improving distance perception under water was investigated. Submerged subjects either kept their heads stationary or rotated their heads about a vertical axis while judging the distance of objects placed 4-15 ft. away. Both before and after training with feedback to increase judgment accuracy, head movement did not significantly improve performance. Water turbidity and loss of position constancy are two probable reasons for the failure to replicate the positive results previously obtained in air.

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INTRODUCTION

Divers are rarely accurate when they estimate the distance of an object under water.[1,2] Due to the combined effects of optical distortion and water turbidity, distances may be under- or overestimated, depending on whether the water is clear or turbid.[3,4] One method for improving the accuracy of distance estimation is direct training. If divers are informed of the correct distance after each of a series of judgments, they quickly learn to compensate for their errors.[4-6] An entirely different approach to this problem was examined in the present experiment. When an observer fixates on an object and moves his head, other objects in the visual field appear to move relative to the fixated object. The velocities and directions of movement are dependent on the relative distances of the various objects. This source of distance information is known as monocular movement parallax. It has recently been shown that rhythmic head rotation about a vertical axis improves absolute distance perception when the usual sources of distance information are absent.[7] Furthermore, specific training in the use of motion parallax leads to very accurate distance judgments. Since poor distance perception occurs under water, it was considered likely that head movement would improve accuracy under water just as it does in air.

METHOD

Subjects

Thirty Navy enlisted men served as subjects. Most had little or no previous diving experience, and only a few had SCUBA experience. None had any experience with the experimental situation.

Apparatus

The experiment was run in an outdoor, above-ground swimming pool which was 20 ft. in diameter and had a water depth of 44 inches. The apparatus, which was similar to the one previously used in air,[7] was designed to permit presentation of targets at various distances with minimal distance information available. The subject sat beneath the surface (breathing through a snorkel) with his back against the wall of the pool. The field of view was restricted by a large black screen; at 2 ft. from the subject, its rectangular opening was 62.5° x 6°. A white background, 24° wide with an effective height of 6°, was mounted against the opposite side of the pool, 18 ft. from the subject. The targets were black strips, varying in width from 1-3/4 to 7-1/2 in. When placed at the appropriate distances from the subject, a constant retinal width of 2.4° was maintained. The effective target height was always 6°. In order to provide

parallax information, a 1/2 in. wide, vertical black rod was mounted 3 ft. from the subject (1 ft. behind the screen), 4° to the left of the target. Head rotation about a vertical axis produced relative movement between this reference rod and the target, the extent and angular velocity of the movement increasing with increased target distance.

Procedure

The subjects were assigned to one of two groups, 15 subjects in each. Members of the Parallax Group rotated their heads rhythmically from side to side, about a vertical axis. For the Head Fixed Group, there was no motion parallax information. These subjects held their heads as motionless as possible, using a chin rest. All viewing was monocular. There were three phases to the experiment, an intial test (T_1), a training session, and a final test (T_2). The basic test distances were 4, 5, 7, 9, 12, and 15 ft. Each distance was presented twice, in random order. Other distances, including half-foot values, were included during training. Training consisted of the presentation of 10 different distances, with the subject being informed of the correct distance after each judgment. Prior to training, members of the Parallax Group were informed of the nature of motion parallax and were encouraged to use this information in making their judgments.

Each subject wore a facemask, snorkel, weightbelt, and usually a rubber wet-suit jacket. They were instructed to judge the distance of the target to the nearest foot or half-foot. Since the subject remained submerged during an entire series of judgments, he signalled each judgment by raising an appropriate number of fingers above the surface. A shutter covered the viewing opening between judgments.

In the data analysis, the two estimates of each subject at each distance were averaged, and geometric means were determined. In addition, power-function exponents were computed by finding the slope of the best-fitting straight line relating log judged to log physical distance.

RESULTS

The results are shown graphically in Fig. 1, and an analysis of variance of the logarithmically transformed data is summarized in Table I. Although the judgments were slightly more accurate (nearer to the physical distance) for Parallax than for Head-Fixed, these differences were not statistically significant. Training significantly improved performance for both head movement conditions, and the amount of improvement increased with increased distance.

The power-function exponents, along with the coefficients of determination ($\underline{r}^2$) are listed in Table II. The larger exponent for Parallax, both before and after training, indicates better distance discrimination for this condition. However, the differences are much less than previously reported for judgments in air.[7]

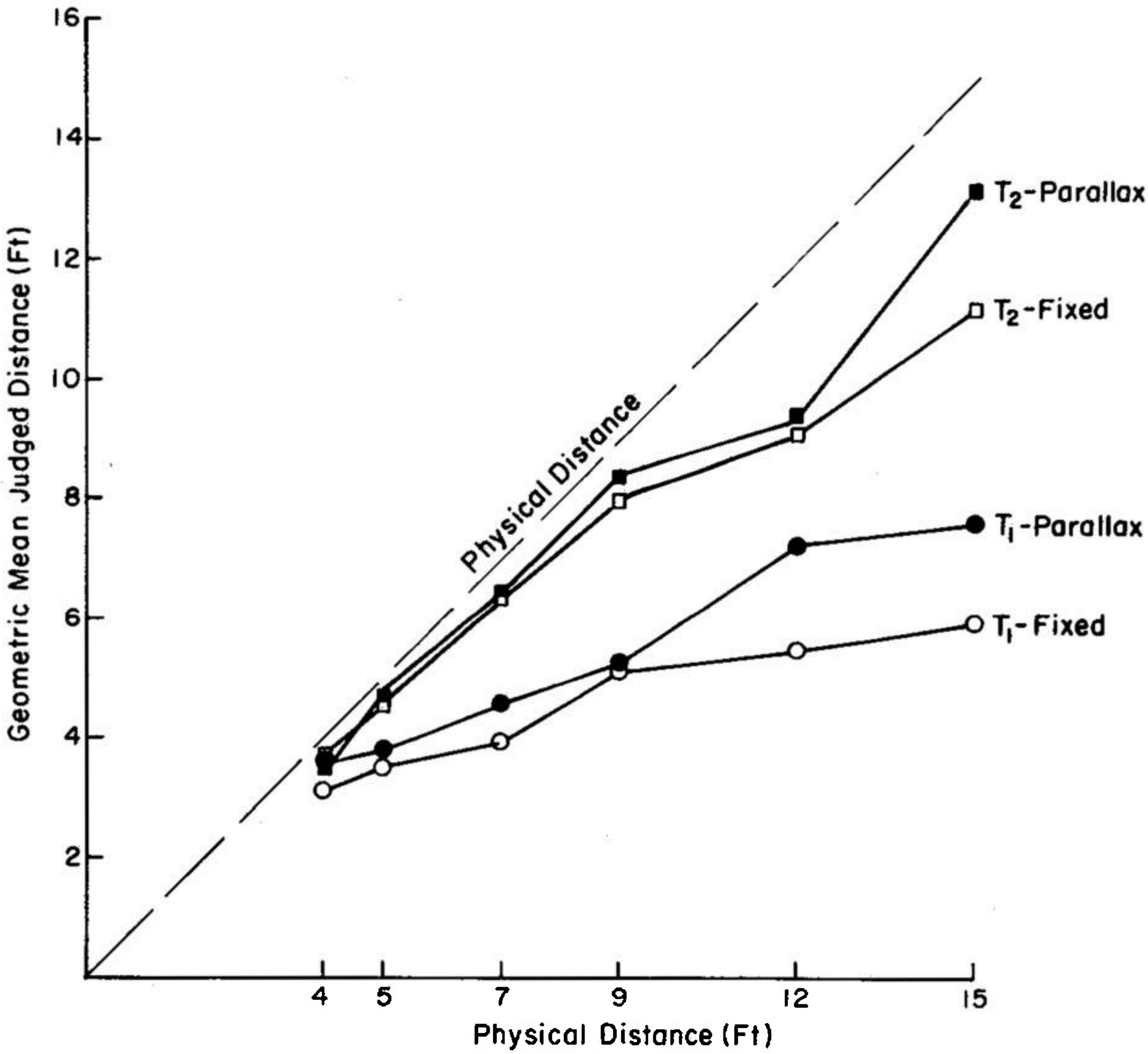

Fig. 1. Geometric mean distance estimates for the Head Fixed and Motion Parallax groups, before (T_1) and after (T_2) training.

Table I - Analysis of Variance

Source	df	MS	F
Between Ss	29		
A (Fixed-Parallax)	1	.146	1.33
Ss WG	28	.110	
Within Ss	330		
B (T_1-T_2)	1	2.242	24.55*
AB	1	.037	.41
B x Ss WG	28	.091	
C (Distance)	5	1.488	85.13*
AC	5	.016	.90
C x Ss WG	140	.017	
BC	5	.109	5.51*
ABC	5	.007	.36
BC x Ss WG	140	.020	

* $p < .001$

Table II - Power-Function Exponents

Condition	T_1		T_2	
	Exponent	r^2	Exponent	r^2
Head Fixed	.51	.97	.82	.99
Parallax	.60	.96	.95	.98

DISCUSSION

The results indicate that motion parallax does not significantly improve the accuracy of distance estimation under water. Although distance discrimination was slightly better with head movement (higher exponents), the small advantage is not of practical value.

Two possible reasons for the negative results may be identified. With a reduction in the available distance information (monocular viewing, reduced field of view, targets of equal retinal size), distance perception is actually better under water than in air. The turbidity of the water, even when the water is quite clear, causes objects to look less distinct as they are moved further away. This effect produces an added source of distance information which is not present in air. Thus a comparison of the T_1-Fixed results between the present water and the previous air experiment[7] reveals more accurate initial judgments in water. The advantage of the water environment is even more marked after training, since training enables the observer to make better use of the additional distance information present under water. These facts can partially explain the limited value of motion parallax under water. Since with head fixed performance is better under water to start with, there is less room for improvement when parallax information is added.

A second possible factor is the loss of position constancy under water. When the head is moved in air, the visual field remains stationary because the amount of retinal image movement matches the amount of head movement. But under water, optical distortion upsets the head-image match and objects appear to jump from side to side as the head is rhythmically rotated.[8] This effect probably caused the target and reference strip to move in the current experiment, thus making it more difficult for motion parallax information to be extracted.

CONCLUSION

It was again shown that the accuracy of distance estimation under water was very effectively improved through training with feedback. The additional improvement resulting from the use of motion parallax was too small to be of practical value.

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